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PUBLISHED BY ELSEVIER INC.

ISSN 1936-8798/08/$34.00
DOI: 10.1016/j.jcin.2008.05.004

Improvement in Survival Following Successful Percutaneous Coronary Intervention of Coronary Chronic Total Occlusions: Variability by Target Vessel

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Objectives This study compared the survival benefit of opening a chronic total occlusion (CTO) of the left anterior descending (LAD), left circumflex (LCX), or right coronary artery (RCA).

Background Previous analyses demonstrate improved survival following successful percutaneous coronary intervention (PCI) for CTO.

Methods Eligible patients underwent attempted CTO PCI in a single vessel. Procedural success rates were calculated for each vessel. The primary end point was survival at 5 years, compared across target vessel groups stratified by procedural success.

Results There were 2,608 patients included. The LAD was the target vessel in 936 (36%), the LCX in 682 (26%), and the RCA in 990 (38%) patients. Angiographic success rates for LAD were 77%, LCX 76%, and RCA 72%. Baseline demographics and comorbidities were well matched, though there were significantly more males in the LCX compared with LAD or RCA groups (80% vs. 75% and 73%, respectively, $p = 0.005$). Procedural success compared with failure was associated with improved 5-year survival in the LAD (88.9% vs. 80.2%, $p < 0.001$) group, but not in the LCX (86.1% vs. 82.1%, $p = 0.21$) and RCA groups (87.7% vs. 84.9%, $p = 0.23$). In multivariable analysis, CTO PCI success in the LAD group remained associated with decreased mortality risk (HR: 0.61, 95% CI: 0.42 to 0.89).

Conclusions The data suggest that PCI for CTO of the LAD, but not LCX or RCA, is associated with improved long-term survival. This information may assist in selecting patients for attempted CTO PCI. (J Am Coll Cardiol Intv 2008;1:295–302) © 2008 by the American College of Cardiology Foundation

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Manuscript received February 14, 2008; revised manuscript received April 8, 2008, accepted April 9, 2008.

Chronic total artery occlusion (CTO) of a coronary artery is identified in 13% to 23% of all patients referred for coronary angiography and accounts for 7.2% to 15.6% of all percutaneous coronary intervention (PCI) attempts (1–4). Successful recanalization of CTO by PCI is associated with better symptom relief, lower risk of subsequent myocardial infarction (MI), and better long-term survival when compared with unsuccessful PCI (5–7). Other recent studies dispute these findings, particularly in patients with occluded infarct-related arteries (8–11). To date, no study has examined the potential for differential benefit of CTO recanalization depending upon the target vessel (e.g., left anterior descending [LAD], left circumflex [LCX], or right coronary artery [RCA]).

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Abbreviations and Acronyms

CABG = coronary artery bypass graft

CAD = coronary artery disease

CCS = Canadian Cardiovascular Society

CTO = chronic total occlusion

GP = glycoprotein

LAD = left anterior descending

LCX = left circumflex

MI = myocardial infarction

PCI = percutaneous coronary intervention

RCA = right coronary artery

The current study was designed to determine procedural success, in-hospital outcomes, and long-term survival in patients undergoing PCI of a single CTO and to compare these outcomes across each of the 3 major epicardial coronary target arteries stratified by procedural success.

Methods

Patient population. Patients were identified using the PCI registry at the Mid America Heart Institute. All patients undergoing attempted PCI of a single CTO between June 1980 and May 2004 were included in this analysis. Details of data collection for this registry have been previously published (5). Dedicated personnel prospectively recorded information, including baseline demographics, clinical and procedural characteristics, and in-hospital outcomes. Long-term survival was ascertained using hospital records and the U.S. Social Security Death Master File, which has been shown to be equivalent to the National Death Index (12). All patients gave informed consent, and the local Institutional Review Board approved the study.

Definitions. Chronic total occlusion was defined as a lesion that displayed Thrombolysis In Myocardial Infarction flow grade 0 to 1 on initial angiography. Patients with acute MI within 7 days pre-procedure, CTO of a venous or arterial bypass conduit or left main coronary artery, or undergoing multivessel PCI were excluded. Patients undergoing multivessel PCI were not eligible for inclusion. Each patient was included in all analyses only once, based on the earliest procedure recorded in the database. The target vessel was assigned as 1 of the 3 major epicardial vessels if the PCI was attempted on that vessel or 1 of its branches (e.g., attempted PCI of an obtuse marginal branch of the LCX was included in the LCX group).

Angiographic success was defined as successful balloon dilation of the lesion with or without stent placement and <40% residual stenosis. Procedural success was defined as angiographic success with no in-hospital major adverse cardiac event, defined as death, MI with new Q waves on electrocardiogram, or urgent target vessel revascularization (including both repeat PCI and coronary artery bypass graft [CABG] surgery). Non–Q-wave MI was defined as elevation of creatine kinase-myocardial band fraction to >3 times the upper limit of normal with recurrent ischemic symptoms following PCI. Severe angina was defined as Canadian Cardiovascular Society (CCS) class III to IV, and renal insufficiency as any serum creatinine >1.5 mg/dl. Current smoking was any active smoking within 1 year. Stroke was defined as new-onset neurological symptoms lasting >24 h with radiographic and/or neurologic confirmation of an event. Hypertension, hypercholesterolemia, and diabetes mellitus were recorded in patients on medical therapy or who self-reported the diagnosis. The number of diseased vessels was assessed by the physician performing PCI. A vessel with >50% angiographic stenosis was considered diseased.

PCI. A PCI was performed using the standard over-the-wire technique as previously described (13). Over time, the technique underwent significant modification, including marked improvement in devices, case selection, and adjunctive pharmacotherapy. Post-procedural electrocardiograms were routinely assessed for new Q waves; however, cardiac troponin, creatine kinase, and creatine kinase-myocardial band fraction were not routinely collected.

Statistical analysis. The overall group was divided into subgroups based upon the target vessel. In order to display any differences in subpopulations, baseline characteristics were then compared between vessels using the Student *t* test for continuous variables and chi-square or the Fisher exact test for discrete variables. Data are presented as mean ± standard deviation for continuous variables and as percentages for discrete variables. The primary end point for this analysis was 5-year survival. A priori, the groups of interest were defined by procedural success/failure for each vessel subpopulation. In order to protect against multiple comparisons, a survival analysis with a vessel by procedural success interaction was performed first. This interaction term was statistically significant, so further survival analyses using log-rank tests were used to compare the survival curves between procedural success/failure groups over time for each vessel. Kaplan-Meier curves were used to depict survival for

Table 1. Demographics

Variable	Target Vessel LAD (n = 936)	LCX (n = 682)	RCA (n = 990)	p Value
Age, yrs, mean (SD)	62 (12)	61 (12)	62 (12)	0.30
Male gender, n (%)	699 (75)	541 (80)	717 (73)	0.005
Current smoking, n (%)	571 (65)	445 (69)	683 (71)	0.007
Diabetes mellitus, n (%)	211 (23)	155 (23)	207 (21)	0.59
Hypertension, n (%)	485 (52)	372 (55)	550 (56)	0.24
Hyperlipidemia, n (%)	570 (63)	453 (67)	656 (67)	0.05
Prior PCI, n (%)	367 (39)	275 (40)	373 (38)	0.54
Prior CABG, n (%)	155 (17)	155 (23)	160 (16)	<0.001
Prior MI, n (%)	474 (51)	351 (52)	458 (46)	0.06
Prior CHF, n (%)	55 (5.9)	25 (3.7)	45 (4.5)	0.11
Ejection fraction, % (SD)	37 (24)	37 (25)	40 (24)	0.006
Renal insufficiency, n (%)	32 (3)	24 (4)	25 (3)	0.41
Severe angina, n (%)	556 (60)	403 (59)	576 (58)	0.84

CABG = coronary artery bypass graft; CHF = congestive heart failure; LAD = left anterior descending; LCX = left circumflex; MI = myocardial infarction; PCI = percutaneous coronary intervention; RCA = right coronary artery; SD = standard deviation.

groups by target vessel and subgroup of procedural success. Survival analyses using log-rank tests were used to compare the survival curves between groups over time. Baseline demographics were compared between those with and without angiographic success to identify significant differences between groups that may affect the primary outcome. A survival analysis using the Cox proportional hazards survival model and adjusted for age, gender, current smoking, prior CABG, number of diseased vessels, angina severity, and glycoprotein (GP) IIb/IIIa inhibitor use was performed to assess the independent contribution of successful CTO PCI to long-term outcomes. Secondary end points included a major adverse cardiac event during the hospital admission for PCI. To assess the impact of clinical variables on procedural success, a multivariable analysis was performed including multivessel coronary artery disease (CAD), male gender, smoking, diabetes mellitus, hypertension, hypercholesterolemia, prior PCI, prior MI, history of congestive heart failure, history of chronic renal insufficiency, prior CABG, or GP IIb/IIIa inhibitor use as variables of interest and performed separately for each target CTO vessel. All analyses were performed using SAS version 9.1 (SAS Institute, Cary, North Carolina) with p values $\leq$ 0.05 considered significant.

Results

Baseline demographics. A total of 36,095 PCIs were performed between June 1980 and May 2004. There were 2,979 (8.3%) attempted CTO PCIs during this period. Of these, 2,608 (88%) were eligible for this analysis. Among all patients, 20.6% had CCS class I angina and 58.9% had CCS class III to IV. By target vessel, CTO PCI was performed on the LAD in 936 (36%), LCX in 682 (26%), and RCA in 990 (38%) patients. Baseline patient characteristics by target vessel are presented in Table 1. Male gender and prior CABG were significantly more common in LCX patients, but current smoking was more common in the RCA group. Mean left ventricular ejection fraction was significantly greater in patients with a RCA target vessel compared with LAD or LCX (0.37 ± 0.24 vs. 0.37 ± 0.25 and 0.40 ± 0.24, respectively, p = 0.006). There were no differences in angina severity across groups.

Procedural characteristics. Overall, 468 patients (18%) received stents, most commonly in the RCA group (Table 2). Use of other adjunctive therapies, including directional or rotational atherectomy, laser, and GP IIb/IIIa inhibitors, was relatively uncommon and did not differ by target vessel.

Angiographic success rates varied across groups (Table 2). In the entire study group, patient characteristics among those with angiographic success were similar to the group with angiographic failure. Among the LAD subgroup, however, those with successful CTO PCI were younger, less often male, had lower prevalence of smoking and prior CABG, and had a higher mean ejection fraction compared with those with unsuccessful PCI (Table 3). Among LCX patients, history of prior CABG was more common in the group with procedural failure than success (29% vs. 21%, p = 0.03). There were no significant demographic differences between the RCA patients with success versus failure.

In-hospital complications. In-hospital complications, including death, target vessel revascularization, and major adverse cardiac event rates, were more common in the LAD CTO group (Table 4). In-hospital CABG was most common in the RCA CTO group. Procedural success rates for the LAD, LCX, and RCA groups were 75%, 75%, and 71%, respectively (p = 0.06) (Table 2). Overall, in-hospital

JACC: CARDIOVASCULAR INTERVENTIONS, VOL. 1, NO. 3, 2008
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Table 2. Procedural Characteristics

Procedure Information	Target Vessel LAD (n = 936)	LCX (n = 682)	RCA (n = 990)	p Value
Number of diseased vessels, n (%)				< 0.001
1	335 (36)	117 (17)	247 (25)	
2	301 (32)	234 (34)	386 (39)	
3	300 (32)	331 (49)	357 (36)	
GP IIb/IIIa inhibitor, n (%)	96 (10)	72 (11)	103 (10)	0.98
Stent deployed, n (%)	149 (16)	113 (17)	206 (21)	0.01
Atherectomy	7 (0.7)	7 (1.0)	5 (0.5)	0.47
Rotablator	25 (2.7)	13 (1.9)	29 (2.9)	0.42
Laser	7 (0.7)	10 (1.5)	17 (1.7)	0.16
Residual dissection, n (%)	150 (18)	126 (21)	173 (20)	0.32
Angiographic success, n (%)	719 (77)	515 (76)	711 (72)	0.03
Procedural success, n (%)	702 (75)	509 (75)	699 (71)	0.06

GP = glycoprotein; other abbreviations as in Table 1.

mortality among patients in the LAD group was significantly greater than the RCA or LCX groups (Table 4). Because all deaths are considered procedural failures, the in-hospital mortality rate in patients with unsuccessful CTO PCI of the LAD (n = 234) was 7.7% (n = 18).

Predictors of procedural success. In the LAD group, smoking (OR: 0.60, 95% CI: 0.42 to 0.85), increasing age per 10 years (OR: 0.86, 95% CI: 0.75 to 0.99), and multivessel CAD (OR: 0.43, 95% CI: 0.29 to 0.61) were associated with a lower likelihood of procedural success, but GP IIb/IIIa use (OR: 2.23, 95% CI: 1.17 to 5.05) was associated with increased success. Among those in the LCX group, prior CABG was associated with decreased procedural success (OR: 0.61, 95% CI: 0.41 to 0.92), but GP IIb/IIIa use was associated with increased success (OR: 2.57, 95% CI: 1.07 to 6.17). Glycoprotein IIb/IIIa use was associated with increased procedural success in the RCA group (OR: 2.56, 95% CI: 1.36 to 4.80).

5-year survival. Average follow-up was 10.5 years for LAD patients, 9.8 years for LCX patients, and 9.9 years for RCA patients. Procedural success compared with failure was associated with improved 5-year survival in the LAD (88.9% vs. 80.2%, $p < 0.001$) groups, but not in the LCX (86.1% vs. 82.1%, $p = 0.21$) and RCA groups (87.7% vs. 84.9%, $p = 0.23$) (Figs. 1A to 1C). There was no significant difference in 5-year survival among those with angiographic failure stratified by vessel attempted ($p = 0.49$). Overall, pre-procedural severe angina was associated with decreased 5-year survival (CCS class III-IV 84.6% vs. CCS class I to II 87.3%, $p = 0.046$).

Multivariable adjusted predictors of long-term survival are presented in Figure 2. After adjusting for demographic and procedural differences between the success and failure groups, successful CTO PCI remained associated with improved long-term survival in the LAD group (HR: 0.61, 95% CI: 0.42 to 0.89). The difference was not significant in

Table 3. LAD Procedural Success Demographics

Demographics	LAD Success (n = 702)	LAD Failure (n = 234)	p Value
Age, yrs (SD)	62 (12)	64 (12)	0.02
Male gender, n (%)	512 (73)	187 (80)	0.03
Smoking current, n (%)	409 (62)	162 (73)	0.003
Diabetes, n (%)	153 (22)	58 (25)	0.34
History of hypertension, n (%)	364 (52)	121 (52)	0.97
History of hyperlipidemia, n (%)	424 (62)	146 (65)	0.45
Prior PCI, n (%)	270 (39)	97 (42)	0.42
Prior CABG, n (%)	103 (15)	52 (22)	0.007
Prior MI, n (%)	357 (51)	117 (50)	0.82
History of CHF, n (%)	40 (5.7)	15 (6)	0.69
Ejection fraction, %, mean (SD)	38 (24)	35 (24)	0.09
Severe angina, n (%)	424 (61)	132 (57)	0.29

Abbreviations as in Table 1.

Table 4. In-Hospital Outcomes

	LAD (n = 936)	LCX (n = 682)	RCA (n = 990)	p Value
Death, n (%)	18 (1.9)	3 (0.4)	5 (0.5)	0.002
MI, n (%)	26 (2.8)	25 (3.7)	24 (2.4)	0.32
Q-wave, n (%)	2 (0.2)	1 (0.1)	5 (0.5)	0.35
Target vessel revascularization, n (%)	13 (1.4)	2 (0.3)	3 (0.3)	0.006
Bypass surgery, n (%)	25 (2.7)	10 (1.5)	35 (3.5)	0.04
Stroke, n (%)	0 (0.0)	1 (0.1)	1 (0.1)	0.54
Major adverse event, n (%)	37 (4.0)	11 (1.6)	19 (1.9)	0.003
Vascular complication, n (%)	15 (1.6)	10 (1.5)	14 (1.4)	0.94
Surgical repair, n (%)	6 (0.6)	2 (0.3)	4 (0.4)	0.56
Bleeding requiring transfusion, n (%)	10 (1.1)	6 (0.9)	10 (1.0)	0.93

Abbreviations as in Table 1.

the LCX (HR: 0.84, 95% CI: 0.53 to 1.32) and RCA groups (HR: 0.95, 95% CI: 0.63 to 1.44). Severe angina did not significantly affect survival in adjusted analyses. Age (per 10-year increase) predicted mortality in all 3 groups, but multivessel CAD and GP IIb/IIIa inhibitor use predicted mortality only in the LAD group. Current smoking predicted mortality in the RCA group (Fig. 2).

Discussion

Our findings suggest a survival benefit of successful CTO PCI of the LAD (as compared to CTO PCI failure) that is not evident in the LCX or RCA subpopulations. Procedural success was associated with an improvement in survival only among those with LAD CTO. There was no similar improvement in survival following successful CTO PCI of the LCX or RCA. To our knowledge, our study is the first to identify a differential benefit by CTO vessel treated in a large group.

Our hypothesis that the survival advantage conferred by successful CTO PCI depends on the culprit vessel was based on previous studies suggesting that LAD occlusion either in acute MI (14,15) or chronic stable coronary syndromes (16) is prognostically significant, whereas lesions in the LCX and RCA are less so. Finding this association between procedural success and improved survival in the LAD but not LCX and RCA groups supports this hypothesis. We also identified increased risk in the LAD group, with a high cost (i.e., in-hospital mortality) of CTO PCI failure. Although overall in-hospital mortality was 1.9% in the entire group, it was 7.7% among patients with failed attempt at CTO PCI of the LAD. This observation also raises questions about how to optimally select patients for CTO PCI in the future.

Prior studies have given discrepant results when evaluating long-term survival following CTO PCI. Recently, investigators at the Mayo Clinic reported technical failure of CTO PCI was not associated with increased 10-year mortality (10). Although these findings differ from others (5,6), they highlight the need for further study to optimize medical decision making.

In the current study, the prevalence of severe angina did not differ between patients with procedural success or failure or by target vessel. Overall, 5-year survival following attempted CTO PCI was poorer among patients with severe pre-procedural angina. However, in multivariable analysis, angina class had no significant association with long-term survival. This differs from prior reports, in which increased mortality correlated with severity of angina in stable outpatients (17), and improvements in left ventricular function following CTO PCI correlated with angina severity (18).

It is possible that some of these clinical variables are related directly to procedural success, thus influencing survival. Although our primary interest was not to define clinical variables associated with procedural success of attempted CTO PCI, our data do provide interesting observations. First, GP IIb/IIIa antagonist use was associated with procedural success in all 3 study groups. In the LAD group, smoking, increased age (per 10 years), and single-vessel CAD were associated with decreased procedural success, but in the LCX group, prior CABG was associated with decreased procedural success. Multivessel CAD has previously been associated with technically unsuccessful CTO recanalization (7). Other factors that may impact success, such as lesion length and morphology, calcification, and collateralization, were not evaluated in this study.

It is the task of the interventional cardiologist to incorporate this sometimes discordant data into the decision-making process when faced with a patient presenting with a CTO. The presence of a CTO on diagnostic angiography is known to impact selection of treatment strategy, decreasing the likelihood of PCI (19). There are several potential reasons why PCI may be deferred, 1 of which is the presence of collateral vessels. However, the "protection" offered to at-risk myocardium is limited, with a normal coronary flow reserve in only 7% of collateralized vessels, and coronary steal syndrome in one-third of interrogated vessels (20).

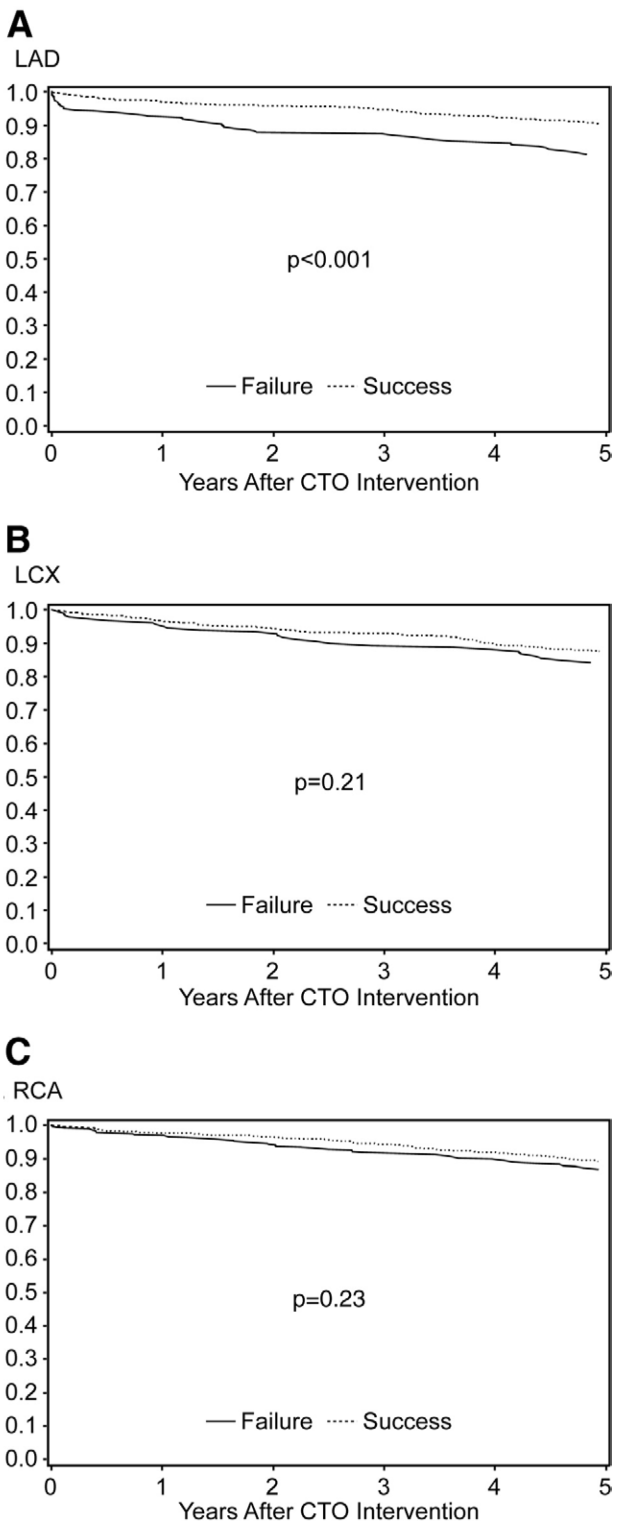

Figure 1. Survival Following Successful Versus Failed CTO PCI

Kaplan-Meier survival curves by success versus failure of percutaneous coronary intervention (PCI) of chronic total occlusions (CTO) in **(A)** left anterior descending (LAD), **(B)** left circumflex (LCX), and **(C)** right coronary artery (RCA).

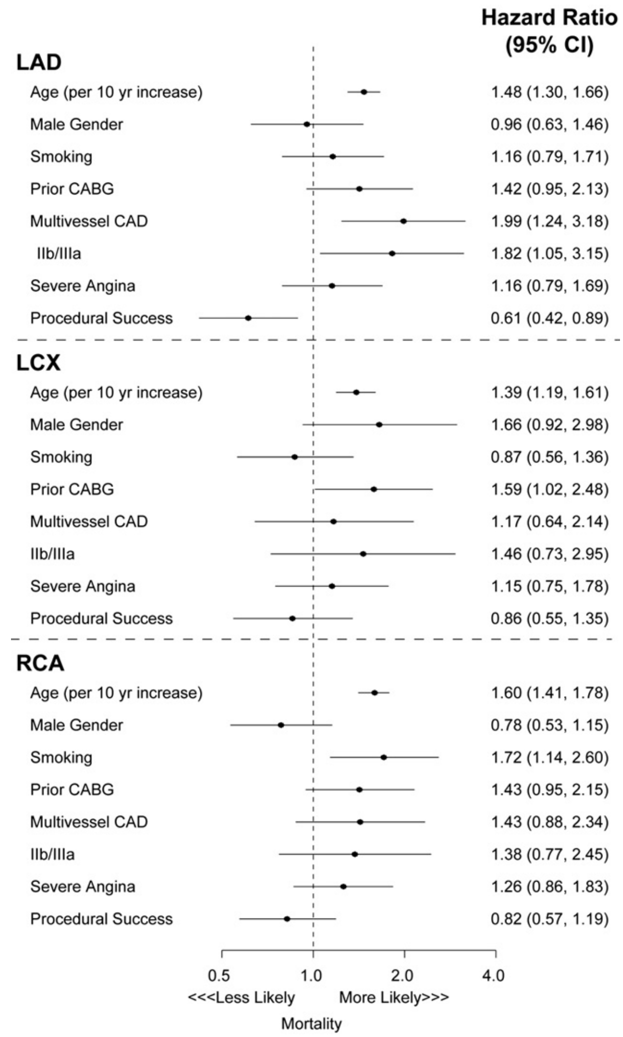

Figure 2. Multivariable Predictors of Survival Following CTO PCI

Multivariable adjusted predictors of long-term survival in patients undergoing percutaneous coronary intervention of chronic total occlusions in left anterior descending, left circumflex, and right coronary artery. CABG = coronary artery bypass graft; CAD = coronary artery disease; other abbreviations as in Figure 1.

Another potential reason for deferring CTO PCI is the absence of severe angina. In multivariable analysis, angina severity had no impact on outcomes in our data. However, approximately 60% of patients included in this study had severe (CCS class III-IV) angina, and all patients included were referred for angiography for clinical indications, including angina, MI, and high-risk noninvasive testing. A limited number of patients in this study (20.6%) had CCS class I angina. Due to these limitations, the current findings may not be generalizable to asymptomatic patients or those with mild angina.

Prior to undergoing attempted CTO PCI, patients should be assured that the potential benefits justify the risks of the procedure. For instance, radiation exposure is significantly higher for CTO PCI than for non–CTO PCI (21). Although some studies suggest that overall survival is improved by successful CTO PCI, the benefit may be limited to certain subgroups. For instance, our group has previously shown no improvement in survival among diabetic patients with successful compared with unsuccessful CTO PCI (22). The current study extends this observation to the target PCI vessel. Those with CTO of the LAD had a 39% relative risk reduction in death at 5 years ($p = 0.01$). The relative risk reduction was 14% in the LCX and 18% in the RCA ($p = NS$ for both) groups. Clarifying the potential survival benefit will hopefully improve communication between physicians and patients and add to the assessment of the potential benefits and risks of CTO PCI by the physician and the patient, increasing the dataset upon which therapeutic decisions may be based.

Improving survival is not the only potential benefit of CTO PCI. There are also improvements in clinical outcomes such as reduced incidence of MI, reduced need for CABG, and significant reductions in angina burden after CTO PCI (7,23). Improvements in regional and global wall motion are evident on myocardial perfusion scintigraphy, echocardiography, and left ventriculography following PCI of CTO (18,24,25). Positive effects on left ventricular remodeling have been reported in patients undergoing cardiac magnetic resonance imaging up to 3 years after CTO PCI (26). These potential benefits may justify attempted CTO PCI despite a lack of significant improvements in survival in some patient subsets.

Optimal timing of CTO PCI is becoming evident in recent publications. In the OAT (Open Artery Trial) (11), PCI of infarct-related arteries 3 to 28 days after MI did not reduce death, recurrent MI, or congestive heart failure over 4 years. The TOSCA (Total Occlusion Study of Canada)-2 substudy (9) reported no improvement in left ventricular function at 1 year. Given these findings, it may be best to allow recovery from acute MI if the presentation to the interventional suite falls within this time frame.

Although the survival benefit associated with successful CTO PCI may be limited to the LAD, there are multiple other benefits of coronary revascularization that need to be considered when recommending therapy. By incorporating the current data with prior reports into a discussion with the patient, it is our hope that health care providers will be able to provide meaningful informed consent. This will encourage the formulation of a treatment plan consistent with the wishes of patients after consideration of all relevant treatment options. It takes a thorough review of the case history, comorbidities, anatomy, and noninvasive testing to enter into a discussion with the patient regarding the procedural risks and benefits. In appropriate situations, CTO PCI can deliver benefits to the patient, including decreased angina burden, improved ejection fraction, and possibly improved long-term survival. It is left to the treating physician to have a thorough dialogue with the patient to arrive at a treatment plan, including CTO PCI when appropriate.

Study limitations. This was an observational study. Hypothesis generation and analysis were retrospectively conducted on prospectively collected data, creating potential post hoc analysis bias. This is an assessment of the benefits of successful CTO PCI as compared with failed CTO PCI. As such, there is no medical therapy group for comparison. These data should not be interpreted as a comparison of PCI and medical therapy in the treatment of CTO. Technology has evolved substantially over the years during which the data were collected. For example, only 18% of the patients in this analysis underwent stent placement, and drug-eluting stents were not available during the study period (only 3 patients in this analysis received drug-eluting stents). During this time, the database was modified to collect more covariables than originally included, thus potentially excluding important predictors of outcomes not recorded in the early experience. Additionally, there are a limited number of anatomic- and lesion-specific variables recorded in the database, including collateralization and specific lesion location, thus limiting our ability to analyze the impact of detailed vessel characteristics on procedural success or long-term survival and potentially biasing our results if there were a disproportionate number of side-branch or distal vessel PCIs in the LCX or RCA groups. The duration of CTO was not known for the entire group, although patients with evidence of MI within the 7 days before the index procedure were excluded from this analysis. Cardiac troponin and creatine phosphokinase data were not routinely collected following PCI during the study period, but only when there was clinical evidence of MI. Electrocardiograms were routinely screened for new Q waves.

Although thorough review of databases from large tertiary care centers provides some insight into the effect of CTO PCI on long-term outcomes, a randomized clinical trial would be necessary to adequately control for the differences between patients with procedural success or procedural failure. Retrospective analyses should be interpreted for with some caution, for while they do provide useful data, they may be subject to unforeseen, unidentifiable confounders that can only be adequately addressed in the setting of a randomized trial.

Conclusions

Our data suggest that successful CTO PCI is associated with an improvement in long-term survival as compared to CTO PCI failure in the subpopulation of patients with LAD CTO. Therefore, attempted PCI of LAD CTO may be justified to improve survival. This improvement is not evident among those with LCX or RCA occlusion, and no comparison to medical therapy is possible with these data.

CTO PCI should be attempted only after a detailed discussion of the potential risks and benefits of the procedure.

Acknowledgments
The authors would like to Josh Murphy for editorial assistance and Jose Aceituno for preparation of graphics.

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